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(54) ELECTRIC ARC AND RADIO FREQUENCY SPECTRUM DETECTION

SPEKTRUMERFASSUNG VON LICHTBÖGEN UND RADIOFREQUENZEN

DETECTION DU SPECTRE DE RADIOFREQUENCES ET D'ARCS ELECTRIQUES

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- **CHONG-YOUNG ET AL. 'Roundoff noise analysis for digital signal power processors'**
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- **noise measurements'**

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EP 0 507 782 B1

Description

The subject invention relates to the detection of radio frequency spectra and of electric arcs, and to systems for acting in response to such radio frequency spectra or to systems for preventing damage from electric arcs.

Given the fact that electric arcs or sparks were the first means for wireless communication, it may be surprising that there persisted a need for detecting a spectrum of radio frequencies in radio frequency noise, such as generated by an electric arc in an electric circuit. However, such a persisting need has been particularly emphasized by electrical fires and other serious damage caused by accidental arcs in electric power supply systems and other circuits. In this respect, while fuses and circuit breakers are capable of preventing serious overload conditions, they have been generally ineffective to prevent electrical fires and other damage from accidental arcs and sparks which frequently occur and persist at current levels below the level at which the fuse will blow or the circuit breaker has been set to trip.

On the other hand, electrical fault detection has been practiced for a long time. For instance, US Patents 1,462,053, by H. M. Stoller, issued 17 July 1923, and 3,308,345 by A. R. Van Cortlandt Warrington, issued 7 March 1967, show different uses of resonant circuitry for fault detection. US Patent 3,728,620, by J. L. Heins, issued 17 April 1973, constitutes the transmission line as a resonant circuit for fault indication and location, utilizing a variable frequency source coupled to one end of the line. US Patents 3,751,606, by C. W. Kaiser, Jr., issued 7 August 1973, and 3,904,839, and 4,229,626, by J. T. Peoples, issued 9 September 1975 and 21 October 1980, respectively, disclose loop fault locators using demodulators, phase comparators, and other electronic circuits.

US Patent 4,006,410, by D. R. Roberts, issued 1 February 1977, proposed pinpointing the location of corona discharges in an electrical system by processing only those high-frequency components that do not propagate along the wires of the system. US Patent 4,609,866, by Loftness, issued 2 September 1986, proposed sequential VHF and UHF reception and amplification for locating electrical systems interference without frequency conversion. US Patent 4,466,071, by B. D. Russell, Jr., issued 14 August 1984, disclosed high impedance fault detection apparatus and methods using a microcomputer system. US Patent 4,543,524 by R. M. Bulley, issued 24 September 1985, may be noted as of interest in the spectrum analyzer area, while US Patent 4,072,899 by R. L. Shimp, issued 7 February 1978, may be noted as of interest in the RF leak detection area.

Australian Patent Specification 63,252 discloses use of a radio frequency mixer in the measurement of noise in a communication signal. An electric arc in the system would generate radio frequency noise over a broad band. However, the noise measuring system of

that Australian Specification would break down such "broadband arc signature" into one of its lower, middle or higher frequency ranges at a time, so that that system could not effectively tell the difference between electric arcs on the one hand and transmission signal noise on the other. Indeed, that Australian Specification does not mention any possibility of detecting electric arcs in the system.

A system specifically designed for detecting a potentially fire generating electrical fault is apparent from International Patent Publication WO-A-90/04278, which represents the closest prior art. Recognizing the possibility of false alarms from radio broadcast and radio frequency security system signals, that system simply cuts off all frequencies in all broadcast bands, leaving for electrical fault detection only a narrow band below the long-wave broadcast band in the 200 KHz range. This, however, excludes from detection the informative frequencies in the megahertz range occurring in typical "arc signatures". Moreover, such sacrifice in sensitivity still does not safeguard against false alarms from radio frequency control signals and security system signals in the 100 KHz range.

Despite this wealth of information and prior proposals, electrical fires and other damage caused by arcs and sparks have continued to devastate electric power supply and other systems, as well as buildings housing them and forests and neighbourhoods in which they are located.

Also, vulnerability to false alarms has been a discouraging problem, inasmuch as switching transients, emissions from radio and television transmitters and other sources can easily trigger false alarms in arc detectors.

In another vein, machinery, circuitry, and apparatus often break down and become damaged in a manner or to an extent that could have been prevented if there had been an early detection of unusual arcing. For instance, commutators of electric motors are often damaged when their carbon brushes wear out, since the metallic brush holder springs then rub against the commutator. Since such wear is accompanied by heavy arcing, an early detection of such arcing could signal the need for preventive action. This is, of course, only a representative example of fields where reliable arc detection could be useful.

According to one aspect of the invention, there is provided a method of detecting a spectrum of a broad band of distinct instantaneous radio frequencies in radio frequency noise, wherein extraneous narrow-band signals are rejected, characterised by mixing said distinct instantaneous radio frequencies with distinct instantaneous radio frequencies of a broad-band signal so as to convert a multitude of those distinct frequencies into a signal substantially at a given combination frequency, and detecting said spectrum as distinct from extraneous narrow-band signals by responding to the presence of a given amount of said signal at said combination frequency.

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According to a second aspect of the invention, there is provided apparatus for detecting a spectrum of a broad band of distinct instantaneous radio frequencies in radio frequency noise, while rejecting extraneous narrow-band signals, characterised by converting means for mixing the distinct instantaneous radio frequencies with distinct instantaneous radio frequencies of a broad-band signal so as to convert a multitude of those distinct frequencies into a signal substantially at a given combination frequency, and detecting means connected to said converting means for detecting said spectrum as distinct from extraneous narrow-band signals by responding to the presence of a given amount of said signal at said combination frequency.

According to one embodiment, the apparatus comprises a radio frequency signal duplicator having an input coupled to a source of that spectrum, a first output for one spectrum as duplicated by that duplicator and a second output for the other spectrum as duplicated by that duplicator, a radio frequency mixer having a first radio frequency input coupled to said first output, a second radio frequency input coupled to said second output and a radio frequency mixer output for a combination of radio frequencies applied to those first and second inputs, and a frequency combination detector having an input coupled to the radio frequency mixer output, and having an output for signalling a detected combination of the distinct instantaneous radio frequencies indicative of said noise.

For a better understanding of the invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:

Fig. 1 is a perspective view of an RF pickup for picking up an arc signature according to one embodiment of the subject invention;

Fig. 2 is a circuit diagram of the pickup of Fig. 1;

Fig. 3 is a block diagram of an amplifier, filter and mixer assembly which can be used in the embodiment of Fig. 1;

Fig. 4 is a block diagram of a receiver-demodulator, timing logic, and relay/LED driver assembly according to an embodiment of the invention for arc detection and damage prevention; and

Fig. 5 is a block diagram of an alternative embodiment of the invention which may, for instance, be used in the apparatus of Fig. 3.

The drawings illustrate methods and apparatus for detecting and acting on spectra of a broad band of distinct instantaneous radio frequencies in radio frequency noise, and also show methods and apparatus for detecting the occurrence of arcs or sparks in electric circuits, all pursuant to presently preferred embodiments of the subject invention.

In the further course of this disclosure, it will be seen

more specifically that these methods and apparatus reject extraneous narrow-band signals having frequencies within the broad band, and detect from the radio frequency noise a combination of a multitude of the distinct instantaneous radio frequencies indicative of the spectrum. For the detection of the occurrence of an electric arc, the illustrated methods and apparatus work from the spectrum of a broad band of distinct instantaneous radio frequencies generated by such arc, and detect an occurrence of that arc by detecting the combination of a multitude of the distinct instantaneous radio frequencies from the broad band of distinct instantaneous radio frequencies generated by that electric arc.

In this respect, electric currents in a circuit and touching wires, loose connections, interruptions, worn carbon brushes, defective or excessively bouncing contacts and other imperfections may generate electric arcs or sparks which, in turn, generate radio frequency (RF) noise which is radiated from the arc and/or travels along the conductors of that electric circuit in accordance with a skin effect. In practice, RF noise generated by an electric arc or spark (hereinafter simply referred to as "arc") comprises a spectrum of a broad band of distinct instantaneous radio frequencies, herein called the "RF signature" of the arc.

A sample of the RF signature of the arc can be picked up with an antenna, a near field capacity coupler, a ferrite core RF transformer, or another RF energy pickup. By way of example, and not by way of limitation, Fig. 1 shows a ferrite core RF transformer 10 for picking up the RF signature of an arc 12 formed in an interruption or other fault between or in circuit wires 13 carrying a load current, or formed by excessive arcing of a switch, commutator or other component. The illustrated transformer 10 comprises a ferrite block composed of core halves 14 and 15 joined along a slice line 16 and held together by a tie wrap 17. The wire 13 in effect acts as a primary winding and a copper strap pickup link 18 acts as a secondary winding of the transformer 10.

Fig. 2 is a circuit diagram of the pickup shown in Fig. 1. The circuit board 20 shown in Fig. 1 carries a filter 21, including input and output matching resistors 22 and 23, and feeding into a pickup output terminal 24. The filter 21 and subsequent filters shown in the drawings have the purpose of assuring that difference frequencies detected as indicative of an arc 12 cannot be simulated in the circuitry by extraneous noise having the same frequency. For instance, there are commercial transmitters and other radio frequency sources that emit signals at frequencies similar to the difference frequency to be detected by the circuitry presently to be described. None of these extraneous signals are to influence the operation of such detection circuitry. High pass or bandpass filters may be used for this purpose. By way of example, the filter 21 and other filters used for the same purpose in the circuitry presently to be described may be designed to eliminate frequencies below 20 MHz, and to pass frequencies from 20 MHz up, if a difference frequency in

the area of 10 MHz is used for example, as more fully described below. In general terms, embodiments of the invention substantially eliminate from the radio frequency noise those components that have a frequency of the combination of the distinct instantaneous radio frequencies as more fully described below.

By way of example, RF components of arc currents reside within a spectral range of from 1 MHz through 500 MHz. In the illustrated embodiment, the RF components below 20 MHz are reduced by the high pass filter 21. The arc signature components of 20 MHz and higher are coupled via connectors 24 and 25 to the input of the amplifier, filter, and mixer assembly shown in Fig. 3. In particular, the filtered RF signature is applied from the pickup output connector 24 to the input connector 25 of a wide band input transformer 26 (XFMR). In an embodiment of the invention, the detector will respond to an arc noise power spectrum level averaging -70 dbm in the 20 MHz to 200 MHz range.

The output signal of the input transformer 26 is applied to the first gain stage 28 via another 20 MHz high pass filter 27 to further reduce signal and/or impulse noise in the spectrum below 20 MHz. That stage 28 preferably is a sealed amplifier module providing 28 db of stable, broadband gain from 0.5 MHz to 500 MHz. This amplifier drives the next 20 MHz high pass filter 29 which in turn drives another 28 db broadband amplifier 31. That second amplifier 31 drives a 1:1 interstage transformer 32. The secondary of that transformer operates in an ungrounded balanced configuration driving two 20 MHz high pass filters 33 and 34 in push-pull. The drive source impedance into each filter is influenced by the terminating impedance presented by the opposite filter. These filters 33 and 34 drive the two input ports 35 and 36 of a balanced mixer 37. Thus the signal level in the region below 20 MHz, applied to either input port of the balanced mixer is attenuated by more than the out-of-band attenuation of a single 20 MHz high pass filter. The output 38 of the mixer 37 is applied to a bandpass filter 39.

Fig. 3 is representative of methods and apparatus for mixing the radio frequency noise with a duplicate thereof, and detecting from such mixed radio frequency noise the difference or other combination of a multitude of the distinct instantaneous radio frequencies. Fig. 3 and equivalents thereof duplicate the radio frequency noise into two paths, such as at 32, 33, 35 and 34, 36, and mix the radio frequency noise from one of such two paths with the radio frequency noise from the other of these two paths to produce a difference or other combination of a multitude of the distinct instantaneous radio frequencies in the arc signature or other radio frequency noise.

Throughout the radio frequency processing system care is taken to minimize signal components and gain availability in the region below 20 MHz. When a wide-band noise power spectrum averaging -70 dbm in the range of 0.5 MHz through 200 MHz is applied to the RF input transformer 26, the signal applied to each input of

the mixer 37 is -35 dbm to -40 dbm in the 20 MHz through 200 MHz region. Below 20 MHz the signal level is less than -70 dbm at each mixer input. The output of the bandpass filter 39 is -50 dbm to -55 dbm centered at the pass-band of the filter 39. A conversion loss of 15 db is correct considering the input levels being applied to the balanced mixer. The term "conversion" is a well-known expression for the frequency conversion that occurs, for instance, in frequency mixers combining two input signals to convert their frequency to their difference frequency or to another combination frequency, such as herein disclosed. In the illustrated embodiment, the output of the frequency converter or mixer 37 is the result of an instantaneous difference frequency between any two or more of the nearly continuous noise pulses which make up the wide band RF signature of the arc being detected.

Extraneous inputs such as relay transients, switch noise, motor brush noise, outside radio transmissions, etc., produce narrow band signals which arrive at the mixer inputs 35 and 36 as common mode inputs. Such signals tend to cancel within the balanced mixer 37 or, if slightly offset in time or frequency, do not produce a significant signal at the difference frequency level. The result is a system that responds to low level, wide band inputs that are the RF signature of an arc, but will not respond to much higher levels of extraneous interference. This provides the stability and false output immunity required.

A preferred embodiment of the invention selected an instantaneous difference frequency of 10.7 MHz for the mixer 38 and bandpass filter 39. This is a commonly used IF frequency for which components are commercially available and which is protected by international convention. Other protected IF frequencies may be used for this purpose.

The processed 10.7 MHz output from the bandpass filter 39 is applied via a terminal 40 to an integrated circuit frequency shift keying (FSK) receiver-demodulator 42 shown in Fig. 4. The signal is coupled to the FSK receiver through a controlled "Q" tuned circuit 43 centered at 10.7 MHz for additional off-frequency signal rejection. A positive supply voltage is supplied via a terminal 140. The terminals 40 and 140 are shown in Figs. 3 and 4 on terminal boards designated as 41 in both figures. Actually, 41 may be one and the same terminal board in both figures, and may contain the extra terminal for the reset 59 shown in Fig. 4.

The output of the FSK receiver-demodulator 42 appears in two forms, at an output 44, a DC proportional to signal level, and at an output 45 a demodulated white noise AC component. The signal level at output 44 does not respond to transient pulse inputs, and there is no AC component at output 45 if an extraneous continuous wave radio signal finds its way into the receiver. That receiver 42 provides its carrier level DC output at 44, and includes a quadrature detector 142 that produces a white noise output at 45 as a result of frequency or phase offsets produced by the balanced mixer 37.

The carrier level DC from receiver output 44 is applied to a voltage follower 46 through the dual time constant circuit 47. The positive-going voltage follower output drives an inverter 48 and the noninverting input of a comparator 49. The combined outputs of the follower 46 and the inverter 48 drive the two-color LED 51. This LED is normally green but will transition through orange to red as the length and/or severity of an arc event increases. This LED 51 is referred to as the "arc event indicator".

The second output of the follower 46 is applied to the noninverting input of the comparator 49 through a dual time constant network 52 including a capacitor 53. The demodulated white noise AC component from the output 45 of the receiver 42 is AC coupled and clamped at 54 to provide a negative-going DC proportional to the amplitude of the demodulated noise. It may be recalled in this respect that the quadrature detector within the integrated circuit receiver 42 produces white noise output at 45 as a result of frequency or phase offsets produced by the balanced mixer 37. The negative-going DC which is proportional to demodulated noise amplitude is applied to dual time constant network 56 which includes a capacitor 57 and which drives the inverting input of comparator 49.

To toggle and latch the comparator 49 both DC inputs must be present and cross through the DC level of the other. The rate at which the DC levels charge and discharge the capacitors 53 and 57 associated with each input is determined by the dual RC time constants of networks 52 and 56. These values are different for various end result requirements. When the comparator 49 is toggled and latched, it is reset by applying ground to pin 141 of connector 41, such as with a pushbutton 59.

During normal operation the output of the comparator 49 is low. This output is coupled to the gate of a field-effect transistor (FET) 61. The drain of that FET is high and is coupled to the gate of another FET 62. With its gate held high, FET 62 is saturated and a relay 63 is energized. The sources of both FET 61 and FET 62 are connected to a dual-color LED 65. This LED is the arc alarm indicator and is green during normal operation, turning to red when an arc alarm occurs. During the arc alarm condition, current through the green half of LED 65, FET 62 and relay 63 is interrupted causing the green half of the LED 65 to extinguish and relay 63 to de-energize. The comparator 49 changes state, its output goes high causing FET 61 to saturate and operate the red half of LED 65. When the comparator 49 is reset, such as by depressing pushbutton 59, the circuits will return to their normal state.

The box 66 may either be a terminal board to which alarm devices, such as bells, horns, circuit interruptors or power cut-off switches may be connected, or may be symbolic of such alarm devices, interruptors or switches themselves.

In either case, the arc 12 or other potentially damaging arcs detected by the illustrated circuitry or otherwise within the scope of the invention, may be safely ter-

minated before any serious damage has been done.

As a particular advantage, the illustrated embodiment enables the operator to assess the seriousness of the arc. Insignificant arcs will not trigger an alarm, but will nevertheless change the color of the LED 51 to orange. In systems where the alarm condition does not shut down the power supply or disconnect the arcing circuit, the operator can tell from the color of the LED 51, whether the arc is serious or is just of temporary nature.

It is a further advantage of the subject invention that embodiments thereof may be implemented with standard components. For instance, the receiver-demodulator 42 may be a Wideband FSK Receiver of the IC type MC13055 described, for instance, in the MOTOROLA Linear and Interface Integrated Circuits Catalog (1988), pp. 8-65 to 8-70. In that case, the output 44 may be the Carrier Detect pin 13, and the output 45 may be the Data Output pin 16, with the order of the other pins shown on the latter page 8-65 being in effect reversed up and down in the showing of Fig. 4. Reference may also be had to that MOTOROLA Circuits Catalog, pp. 2-57 to 2-60, for an example of an implementation of components 46, 48 and 49 from the Quad Single Supply Comparators IC type LM139, A.

Similarly, reference may be had to the RF/IF Signal Processing Guide by Mini-Circuits (SF-89/90), for an example of a mixer at 37, in the form of the Frequency Mixer, Type SBL-1 on page 18, for an example of components 28 and 31 in the form of Amplifiers of the IC type MAN-1 on pages 38 and 39, for an example of components 26 and 32 in the form of RF Transformers on pages 52 and 53, and for an example of components 21, 27, 29, 33 and 34 in the form of High Pass Filters of the Type PHP-50 shown on page 61. The bandpass filter 39 may be the bandpass filter PBP-10.7 (MHz) made by the same company and described, for instance in Micro-waves & RF (July 1990).

However, the scope of the invention is not limited to specific apparatus. For instance, one or more of the filters shown in the drawings may be omitted, if a reduction in noise rejection can be tolerated, or if noise rejection is effected in another manner. Similarly, the components 32, 33 and 34 constitute a radio frequency signal duplicator having an input coupled to a source of the spectrum to be detected, a first output at 33 for one spectrum as duplicated by that duplicator, and a second output at 34 for the other spectrum as duplicated by that duplicator. The scope of the invention is of course not limited to the use of such components.

The radio frequency mixer 37 has a first radio frequency input 35 coupled to the first output of the signal duplicator, a second radio frequency input 36 coupled to the second output of the signal duplicator, and a radio frequency mixer output 38 for a combination of radio frequencies applied to said first and second inputs, which may, for example, be the difference frequency of distinct instantaneous radio frequencies in the noise spectrum or in the arc signature. However, another kind of frequen-

cy converter may be used instead of these illustrated components within the scope of the invention. As is well known, non-linear elements have been employed for frequency mixing or conversion purposes.

The frequency combination detector 42 has an input, such as at 43, coupled to the radio frequency mixer output 37, and includes an output 44 for a detected difference or other combination of the distinct instantaneous radio frequencies indicative of the electric arc or other noise.

As apparent from this disclosure, various means have been disclosed for substantially eliminating extraneous radio frequency interference, including, for example, high pass filters 21, 27 and/or 29 between the source 12 and the radio frequency duplicator input at 32, having a passband above the difference frequency or other detected combination of the distinct instantaneous radio frequencies. Other means for substantially eliminating extraneous radio frequency interference include the balanced nature and operation of the mixer 37 or other frequency converter and/or the passband filter 39 between the radio frequency mixer output 38 and the frequency combination detector or receiver-demodulator input, having a passband at the difference frequency or other detected combination of the distinct instantaneous radio frequencies.

Fig. 4 further discloses means connected to the frequency combination detector or radio frequency receiver-demodulator 42 for indicating an occurrence of the arc signature or other spectrum. For instance, in addition to the follower 46, inverter 48 and LED 51, or as an alternative thereto, the follower 46, comparator 49, relay 63 and/or LED 65 connected to the radio frequency receiver-demodulator 42 provide an alarm condition in response to occurrence of the arc signature or other spectrum.

The frequency combination detector may include first means 42 for generating a first signal proportional to a signal level at the mixer output 38, and second means 142 for generating a second signal in response to frequency or phase offsets in the radio frequency mixer 37. The apparatus includes third means, such as 46, 47, 48, 51, connected to the first means 42 for indicating an occurrence of the arc signature or other spectrum, and fourth means such as 49, 52, 61, 62, 63, 65, 66, connected to the first and to at least one of the second and third means for providing an alarm condition in response to occurrence of the arc signature or other spectrum.

If the source is an electric arc 12 providing the radio frequency noise to be detected, then means are provided for coupling that radio frequency noise to the radio frequency duplicator or transformer input 25. In principle, an antenna could be used for that purpose. However, to reduce exposure to radio frequency interference, a ferrite core transformer 10 preferably is connected between the arcing circuit 13 or other source and the radio frequency duplicator input or wide band transformer input 25.

Fig. 5 shows an alternative that may be used within the scope of the subject invention when highest performance is not required. Instead of duplicating the radio frequency noise as at 34 in Fig. 3, the circuit of Fig. 5 generates a wide band noise signal also including distinct radio frequencies like the above mentioned radio frequency noise containing a spectrum of a broad band of distinct instantaneous radio frequencies. A wide band noise generator 68 may be substituted for that purpose for the filter 34 in the above mentioned other of the two paths between the transformer 32 and the mixer 37. In this case, there is only one path for the picked-up radio frequency noise from the transformer 32 through the filter 33 to the first mixer input 35, while the second mixer input 36 is supplied by the wide band noise from the generator 68. Any kind of wide band noise generator may be employed, as long as it provides the above mentioned distinct radio frequencies, as is generally the case with noise diodes and the like.

The above mentioned mixer also shown in Fig. 5 this time mixes the radio frequency noise from the transformer 32 with the wide band noise signal from the generator 68 to produce a difference or other combination of a multitude of distinct instantaneous radio frequencies at the mixer output for detection of the arc or other arc signature or other radio frequency spectrum, such as in Fig. 4. In other words, except for the substitution of the wide band noise generator 68 for the high pass filter 34 and the grounding of the lower output of transformer 32, the circuitry may be the same as in Figs. 3 and 4, with or without Fig. 2.

In Fig. 1, the occurrence of an arc in a broken conductor 13 or between conductors has been stressed. However, the arc 12 symbolically shown in Fig. 2 may, for instance, signify excessive arcing at a rotary commutator, in a contactor or in other electrical components. In such cases, too, the circuitry of Figs. 2, 3, 4 or 5 may be used to detect such excessive arcing. The LED 51 may be used to indicate excessive arcing, while the relay 63 may be used to shut off the motor, contactor or other component before the commutator has been worn, the contactor burned or the electrical component otherwise damaged. Remedial action may then be taken before operation is resumed.

Claims

1. A method of detecting a spectrum of a broad band of distinct instantaneous radio frequencies in radio frequency noise, wherein extraneous narrow-band signals are rejected, characterised by mixing (37) said distinct instantaneous radio frequencies with distinct instantaneous radio frequencies of a broad-band signal so as to convert a multitude of those distinct frequencies into a signal substantially at a given combination frequency, and detecting said spectrum as distinct from extraneous narrow-band

signals by responding to the presence of a given amount of said signal at said combination frequency in the output of the mixing step.

2. A method according to claim 1, including the step of substantially eliminating (21, 27, 29) from said radio frequency noise components corresponding in frequency to said combination frequency indicative of said spectrum.
3. A method according to claim 1 or 2, wherein the detecting step comprises the use of a band-pass filter centered substantially on said given combination frequency.
4. A method according to claim 1, 2 or 3, including the step of mixing (37) said radio frequency noise with a duplicate thereof (32-34) and detecting (42) from the mixed radio frequency noise said combination frequency of said distinct instantaneous radio frequencies indicative of said spectrum.
5. A method according to claim 4, including the steps of duplicating said radio frequency noise into two paths (33, 34) and mixing (37) the radio frequency noise from one of said two paths with the radio frequency noise from the other of said two paths to produce said signal substantially at said combination frequency from the multitude of said distinct instantaneous radio frequencies.
6. A method according to claim 1, 2 or 3, including the steps of generating a wide band noise signal (68, Fig. 5) of radio frequencies, the mixing (37) comprising mixing said radio frequency noise with said wide band noise signal to produce said signal substantially at said combination frequency from the multitude of distinct instantaneous radio frequencies present at the input to the mixing step.
7. A method according to any one of the preceding claims, including the steps of generating a first signal (44) proportional to a signal level of said combination frequency, generating a second signal (45) in response to frequency or phase offsets produced by the conversion, indicating (51) an occurrence of said spectrum in response to said first signal and generating an alarm condition (65, 66) from a comparison of said first and second signals.
8. A method according to any one of the preceding claims wherein said spectrum of a broad band of distinct instantaneous radio frequencies is generated by an electric arc (12) and an occurrence of said arc is detected by detecting said combination frequency of a multitude of said distinct instantaneous radio frequencies from said broad band of distinct instantaneous radio frequencies generated by said electric

arc.

9. A method according to any one of the preceding claims wherein said combination frequency is a difference frequency (at 38) of said multitude of distinct instantaneous radio frequencies detected from said radio frequency noise.
10. Apparatus for detecting a spectrum of a broad band of distinct instantaneous radio frequencies in radio frequency noise, while rejecting extraneous narrow-band signals, characterised by converting means (32-37) for mixing the distinct instantaneous radio frequencies with distinct instantaneous radio frequencies of a broad-band signal so as to convert a multitude of those distinct frequencies into a signal substantially at a given combination frequency, and detecting means (42) connected to said converting means for detecting said spectrum as distinct from extraneous narrow-band signals by responding to the presence of a given amount of said signal at said combination frequency.
11. Apparatus according to claim 10, including means (21, 27, 29) coupled to said converting means (32-37) for substantially eliminating components from said radio frequency noise corresponding in frequency to said combination frequency indicative of said spectrum.
12. Apparatus according to claim 10 or 11, wherein the detecting means comprises a band-pass filter (39) substantially centered on said given combination frequency.
13. Apparatus according to claim 10, 11 or 12, wherein the converting means comprises means (32-34) for mixing said radio frequency noise with a duplicate thereof, said detecting means (42) being arranged to detect from the mixed radio frequency noise said output signal produced substantially at said combination frequency from the multitude of said distinct instantaneous radio frequencies.
14. Apparatus according to claim 13, comprising a radio frequency signal duplicator (32-34) having an input coupled to a source of said spectrum, a first output (33) for one spectrum as duplicated by said duplicator and a second output (34) for the other spectrum as duplicated by said duplicator, the converting means being a radio frequency mixer (37) having a first radio frequency input (35) coupled to said first output, a second radio frequency input (36) coupled to said second output, and a radio frequency mixer output (38) for delivering the combinations of radio frequencies applied to said first and second inputs.
15. Apparatus according to claim 14, including a ferrite

core transformer (10) connected between said source (12) and the radio frequency duplicator input.

16. Apparatus according to claim 10, 11 or 12, including a wide band noise generator (68), said converting means including means (37) for mixing said radio frequency noise with wide band noise from said generator (68) to produce said signal indicative of said spectrum substantially at said combination frequency from the multitude of distinct instantaneous radio frequencies present in the radio frequency noise and the output of the generator.
17. Apparatus according to any one of claims 10 to 16, wherein said detecting means (42) is arranged to detect a difference frequency of said multitude of distinct instantaneous radio frequencies as said combination frequency detected from said radio frequency noise.
18. Apparatus according to any one of claims 10 to 17, wherein said frequency combination detecting means is a radio frequency receiver-demodulator (42).
19. Apparatus according to claim 18, including means (46-51) connected to said radio frequency receiver-demodulator for indicating an occurrence of said spectrum.
20. Apparatus according to claim 18 or 19, including means (49-66) connected to said radio frequency receiver-demodulator for providing an alarm condition in response to occurrence of said spectrum.

Patentansprüche

1. Verfahren zum Nachweis eines Spektrums eines breiten Bandes von verschiedenen bzw. bestimmten Momentan-Hochfrequenzen im Hochfrequenz-Rauschen, bei dem Schmalband-Fremdsignale ausgeschieden werden, gekennzeichnet durch Mischen (37) der verschiedenen Momentan-Hochfrequenzen mit bestimmten Momentan-Hochfrequenzen eines Breitband-Signals, um eine Vielzahl der verschiedenen Frequenzen in ein Signal mit im wesentlichen einer vorgegebenen Kombinations- bzw. Schwebungsfrequenz umzuwandeln, und durch Nachweis des genannten Spektrums als verschieden von Schmalband-Fremdsignalen durch Ansprechen auf das Vorhandensein eines gegebenen Betrags des genannten Signals bei der genannten Schwebungsfrequenz im Ausgang der Mischstufe.
2. Verfahren nach Anspruch 1, gekennzeichnet durch substantielles Eliminieren (21, 27, 29) von Rausch-

komponenten aus der genannten Hochfrequenz, die in ihrer Frequenz der für das genannte Spektrum bezeichnenden Schwebungsfrequenz entsprechen.

3. Verfahren nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß der Nachweis-Schritt die Verwendung eines Bandpaß-Filters umfaßt, das im wesentlichen auf die vorgegebene Schwebungsfrequenz zentriert ist.
4. Verfahren nach einem der Ansprüche 1 bis 3, gekennzeichnet durch Mischen (37) des genannten Hochfrequenz-Rauschens mit seinem Duplikat (32 - 34) und Nachweisen (42) der Schwebungsfrequenz der einzelnen Momentan-Hochfrequenzen, die für das Spektrum bezeichnend sind, aus dem gemischten Hochfrequenz-Rauschen.
5. Verfahren nach Anspruch 4, gekennzeichnet durch Duplizieren des genannten Hochfrequenz-Rauschens in zwei Pfade (33, 34) hinein und Mischen (37) des Hochfrequenz-Rauschens eines der beiden Pfade mit dem Hochfrequenz-Rauschen des anderen der beiden Pfade, um das genannte Signal im wesentlichen bei der Schwebungsfrequenz aus der Vielzahl von einzelnen Momentan-Hochfrequenzen zu erzeugen.
6. Verfahren nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß ein Breitband-Rauschsignal (68, Fig. 5) von Hochfrequenzen erzeugt wird und das Mischen (37) erreicht wird durch Mischen des Hochfrequenz-Rauschens mit dem genannten Breitband-Rauschsignal, zum Erzeugen des Signals im wesentlichen bei der Schwebungsfrequenz aus der Vielzahl von einzelnen bzw. bestimmten Momentan-Hochfrequenzen, die am Eingang der Mischerstufe vorliegen.
7. Verfahren nach einem der Ansprüche 1 bis 6, gekennzeichnet durch das Erzeugen eines ersten Signals (44), das proportional zu einem Signalniveau der Schwebungsfrequenz ist, das Erzeugen eines zweiten Signals (45) in Abhängigkeit von durch die Umwandlung erzeugten Frequenz- oder Phasenverschiebungen, Anzeigen (51) des Auftretens des Spektrums in Abhängigkeit von dem ersten Signal und Erzeugen einer Alarmbedingung (65, 66) aus einem Vergleich der genannten ersten und zweiten Signale.
8. Verfahren nach einem der Ansprüche 1 bis 7, dadurch gekennzeichnet, daß das Spektrum eines breiten Bandes von einzelnen bzw. bestimmten Momentan-Hochfrequenzen durch einen elektrischen Lichtbogen (12) erzeugt wird und ein Auftreten des genannten Lichtbogens durch Nachweis der Schwebungsfrequenz einer Vielzahl der einzelnen

Momentan-Hochfrequenzen aus dem breiten Band von durch den genannten elektrischen Lichtbogen erzeugten einzelnen Momentan-Hochfrequenzen aufgespürt wird.

9. Verfahren nach einem der Ansprüche 1 bis 8, dadurch gekennzeichnet, daß die Schwebungsfrequenz eine Differenzfrequenz (bei 38) der genannten Vielzahl von einzelnen Momentan-Hochfrequenzen ist, die aus dem genannten Hochfrequenz-Rauschen ermittelt werden.
10. Vorrichtung zum Nachweis eines Spektrums eines breiten Bandes von einzelnen bzw. bestimmten Momentan-Hochfrequenzen im Hochfrequenz-Rauschen, wobei Schmalband-Fremdsignale ausgeschieden werden, gekennzeichnet durch Umformmittel (32 bis 37) zum Mischen der verschiedenen Momentan-Hochfrequenzen mit bestimmten Momentan-Hochfrequenzen eines Breitband-Signals, um eine Vielzahl der verschiedenen Frequenzen in ein Signal mit im wesentlichen einer vorgegebenen Schwebungsfrequenz umzuwandeln, und Nachweismittel (42), die mit den genannten Umformmitteln verbunden sind, zum Nachweisen des genannten Spektrums als getrennt bzw. verschieden von Schmalband-Fremdsignalen durch Ansprechen auf das Vorhandensein eines gegebenen Betrags des genannten Signals bei der genannten Schwebungsfrequenz.
11. Vorrichtung nach Anspruch 10, gekennzeichnet durch mit den Umformmitteln (32 bis 37) gekoppelte Mittel (21, 27, 29) zum substantiellen Eliminieren von Komponenten aus dem genannten Hochfrequenz-Rauschen, die in ihrer Frequenz der für das Spektrum bezeichnenden Schwebungsfrequenz entsprechen.
12. Vorrichtung nach Anspruch 10 oder 11, dadurch gekennzeichnet, daß das Nachweismittel ein Bandpaß-Filter (39) enthält, das im wesentlichen auf die Schwebungsfrequenz zentriert ist.
13. Vorrichtung nach einem der Ansprüche 10 bis 12, dadurch gekennzeichnet, daß das Umformmittel Mittel (32 bis 34) zum Mischen des genannten Hochfrequenz-Rauschens mit seinem Duplikat enthält, und die Mittel (42) zum Nachweis des genannten Ausgangssignals aus dem gemischten Hochfrequenz-Rauschen vorgesehen sind, wobei das Ausgangssignal im wesentlichen bei der genannten Schwebungsfrequenz aus einer Vielzahl der genannten einzelnen Momentan-Hochfrequenzen gebildet wird.
14. Vorrichtung nach Anspruch 13, gekennzeichnet durch einen Hochfrequenz-Signal-Duplikator (32,

34), der einen auf eine Quelle des genannten Spektrums geschalteten Eingang hat, einen ersten Ausgang (33) für ein durch den Duplikator dupliziertes Spektrum und einen zweiten Ausgang (34) für das andere, durch den Duplikator duplizierte Spektrum, wobei das Umformmittel ein Hochfrequenzmischer (37) ist, der einen ersten mit dem ersten Ausgang gekoppelten Hochfrequenzeingang (35), einen zweiten mit dem zweiten Ausgang gekoppelten Hochfrequenzeingang (36) und einen Hochfrequenz-Mischer-Ausgang (38) zum Liefern der Kombinationen von an den ersten und zweiten Eingängen anliegenden Hochfrequenzen besitzt.

15. Vorrichtung nach Anspruch 14, gekennzeichnet durch einen Ferrit-Kern-Transformator (10), der zwischen die Quelle (12) und den Hochfrequenz-Duplikatoreingang geschaltet ist.
16. Vorrichtung nach einem der Ansprüche 10 bis 12, gekennzeichnet durch einen Breitband-Rauschgenerator (68), wobei die Umformmittel Mittel (37) zum Mischen des Hochfrequenz-Rauschens mit dem Breitbandrauschen des Generators (38) umfassen, um das für das Spektrum bezeichnende Signal im wesentlichen bei der Schwebungsfrequenz aus einer Vielzahl einzelner Momentan-Hochfrequenzen zu erzeugen, die im Hochfrequenz-Rauschen und im Ausgang des Generators vorhanden sind.
17. Vorrichtung nach einem der Ansprüche 10 bis 16, dadurch gekennzeichnet, daß das Nachweismittel (42) dem Nachweis einer Differenz-Frequenz der Vielzahl einzelner Momentan-Hochfrequenzen, als die Schwebungsfrequenz, die aus dem Hochfrequenz-Rauschen aufgefunden wird.
18. Vorrichtung nach einem der Ansprüche 10 bis 17, dadurch gekennzeichnet, daß das die Schwebungsfrequenz aufspürende Mittel ein Hochfrequenz-Empfänger-Demodulator (42) ist.
19. Vorrichtung nach Anspruch 18, gekennzeichnet durch mit dem Hochfrequenz-Empfänger-Demodulator verbundene Mittel (46 bis 51) zum Anzeigen eines Auftretens des Spektrums.
20. Vorrichtung nach Anspruch 18 oder 19, gekennzeichnet durch auf den genannten Hochfrequenz-Empfänger-Demodulator geschaltete Mittel (49 bis 66) zum Liefern einer Alarm-Bedingung in Abhängigkeit vom Auftreten des Spektrums.

55 Revendications

1. Procédé de détection d'un spectre d'une large bande de radiofréquences instantanées et distinc-

tes dans un bruit de radiofréquence, selon lequel les signaux étrangers de bande étroite sont rejetés, caractérisé par le fait de mélanger (37) ces radiofréquences instantanées et distinctes avec des radiofréquences instantanées et distinctes d'un signal de bande large afin de convertir une multiplicité de ces fréquences distinctes en un signal sensiblement à une fréquence synthétisée donnée, et de détecter que ce spectre est distinct des signaux étrangers de bande étroite en réagissant à la présence d'une quantité donnée de ce signal à cette fréquence synthétisée à la sortie de l'étape de mélange.

2. Procédé selon la revendication 1, comprenant l'étape consistant à éliminer sensiblement (21, 27, 29) du bruit de radiofréquences les composantes correspondant en fréquence à la fréquence synthétisée signalant le spectre.
3. Procédé selon la revendication 1 ou 2, selon lequel l'étape de détection comprend l'utilisation d'un filtre passe-bande centré sensiblement sur la fréquence synthétisée donnée.
4. Procédé selon la revendication 1, 2 ou 3, comprenant l'étape de mélange (37) du bruit de radiofréquence avec une copie (32-34) de celui-ci et de détection (42), à partir du bruit de radiofréquences mélangé, de la fréquence synthétisée des radiofréquences instantanées et distinctes signalant le spectre.
5. Procédé selon la revendication 4, comprenant les étapes consistant à dupliquer le bruit de radiofréquences en deux voies (33, 34) et à mélanger (37) le bruit de radiofréquence de l'une de ces deux voies avec le bruit de radiofréquence de l'autre voie afin de produire le signal sensiblement à la fréquence synthétisée à partir de la multiplicité de radiofréquences instantanées distinctes.
6. Procédé selon la revendication 1, 2 ou 3, comprenant les étapes de production d'un signal de bruit de bande large (68, Fig. 5) de radiofréquences, le mélange (37) comprenant le mélange du bruit de radiofréquence avec le signal de bruit de bande large pour produire le signal sensiblement à la fréquence synthétisée, à partir de la multiplicité de radiofréquences instantanées et distinctes présentes à l'entrée de l'étape de mélange.
7. Procédé selon l'une quelconque des revendications précédentes, comprenant les étapes de production d'un premier signal (44) proportionnel à un niveau de signal de la fréquence synthétisée, de production d'un deuxième signal (45) en réponse aux décalages de fréquences ou de phases produits par la con-

version, d'indication (51) de la présence du spectre en réaction au premier signal, et de production d'un état d'alarme (65, 66) à partir d'une comparaison entre les premier et deuxième signaux.

8. Procédé selon l'une quelconque des revendications précédentes, selon lequel le spectre d'une bande large de radiofréquences instantanées et distinctes est engendré par un arc électrique (12) et une présence de cet arc est détectée en détectant la fréquence synthétisée d'une multiplicité de radiofréquences instantanées et distinctes à partir de la bande large de radiofréquences instantanées et distinctes produites par cet arc électrique.
9. Procédé selon l'une quelconque des revendications précédentes, selon lequel la fréquence synthétisée est une fréquence différentielle (en 38) de la multiplicité de radiofréquences instantanées et distinctes détectées à partir du bruit de radiofréquence.
10. Appareil permettant de détecter un spectre d'une large bande de radiofréquence instantanée et distincte dans un bruit de radiofréquences, tout en rejetant les signaux étrangers de bande étroite, caractérisé par des moyens de conversion (32-37) destinés à mélanger les radiofréquences instantanées et distinctes avec des radiofréquences instantanées et distinctes d'un signal de bande large afin de convertir une multiplicité de ces fréquences distinctes en un signal sensiblement à une fréquence synthétisée donnée, et par des moyens de détection (42) reliés aux moyens de conversion pour détecter que le spectre est distinct des signaux étrangers de bande étroite, en réagissant à la présence d'une quantité donnée de ce signal à cette fréquence synthétisée.
11. Appareil selon la revendication 10, comprenant des moyens (21, 27, 29) couplés aux moyens de conversion (32-37) pour éliminer sensiblement les composantes du bruit de radiofréquence correspondant, en fréquence, à la fréquence synthétisée signalant le spectre.
12. Appareil selon la revendication 10 ou 11, dans lequel les moyens de détection comprennent un filtre passe-bande (39) sensiblement centré sur la fréquence synthétisée donnée.
13. Appareil selon la revendication 10, 11 ou 12, dans lequel les moyens de conversion comprennent des moyens (32-34) destinés à mélanger le bruit de radiofréquence avec une copie de celui-ci, les moyens de détection (42) étant conçus pour détecter, à partir du bruit de radiofréquence mélangé, le signal de sortie produit sensiblement à la fréquence synthétisée, à partir de la multiplicité de radiofréquences instantanées et distinctes.

14. Appareil selon la revendication 13, comprenant un duplicateur de signaux de radiofréquence (32-34) possédant une entrée couplée à une source du spectre, une première sortie (33) pour un spectre dupliqué par le duplicateur, et une deuxième sortie (34) destinée à l'autre spectre dupliqué par le duplicateur, les moyens de conversion étant un mélangeur de radiofréquences (37) possédant une première entrée de radiofréquences (35) couplée à la première sortie, une deuxième entrée de radiofréquences (36) couplée à la deuxième sortie, et une sortie (38) du mélangeur de radiofréquences destinée à produire les combinaisons de radiofréquences appliquées aux première et deuxième entrées.
15. Appareil selon la revendication 14, comprenant un transformateur (10) à noyau en ferrite monté entre la source (12) et l'entrée du duplicateur de radiofréquences.
16. Appareil selon la revendication 10, 11 ou 12, comprenant un générateur de bruit de bande large (68), les moyens de conversion comprenant des moyens (37) permettant de mélanger le bruit de radiofréquence avec le bruit de bande large, provenant du générateur (68), afin de produire le signal signalant le spectre sensiblement à la fréquence synthétisée, provenant de la multiplicité de radiofréquences instantanées et distinctes présentes dans le bruit de radiofréquence et la sortie du générateur.
17. Appareil selon l'une quelconque des revendications 10 à 16, dans lequel les moyens de détection (42) sont conçus pour détecter une fréquence différentielle de la multiplicité de radiofréquences instantanées et distinctes à la fréquence synthétisée détectée à parti du bruit de radiofréquence.
18. Appareil selon l'une quelconque des revendications 10 à 17, dans lequel les moyens de détection de fréquence synthétisée sont un récepteur-démodulateur (42) de radiofréquences.
19. Appareil selon la revendication 18, comprenant des moyens (46-51) reliés au récepteur-démodulateur de radiofréquences afin d'indiquer la présence du spectre.
20. Appareil selon la revendication 18 ou 19, comprenant des moyens (49-66) reliés au récepteur-démodulateur de radiofréquences pour produire un état d'alarme en réaction à la présence du spectre.

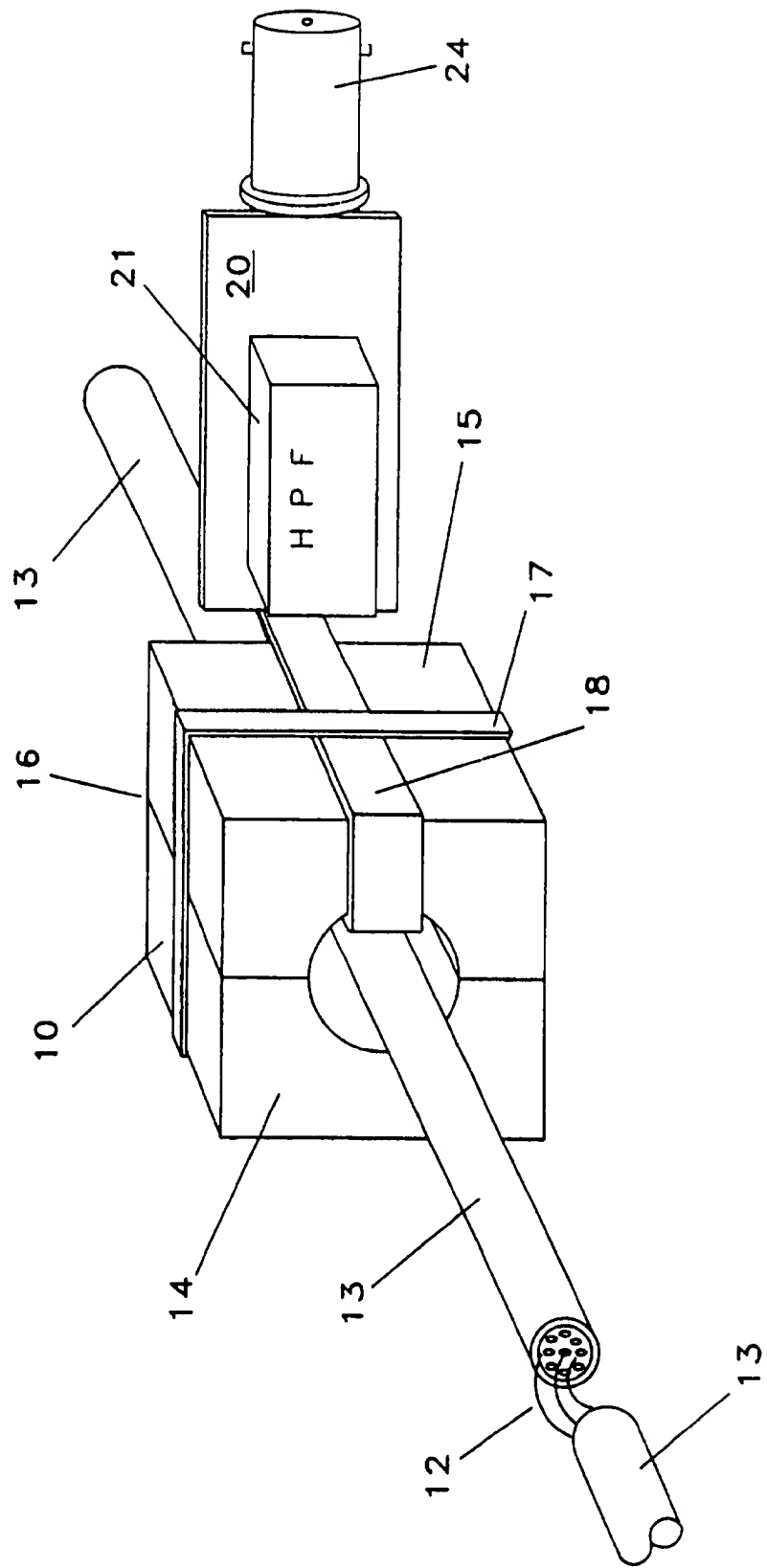


FIG. 1

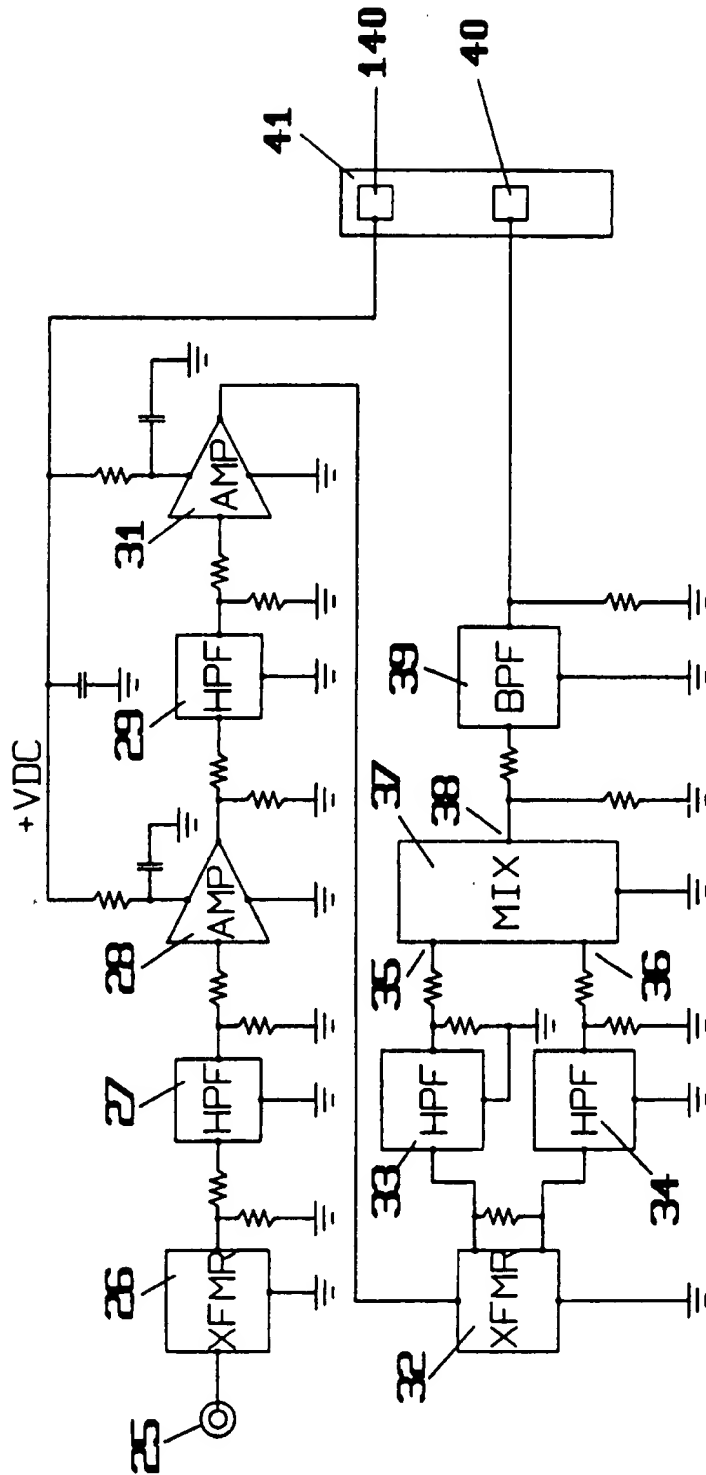


FIG-3

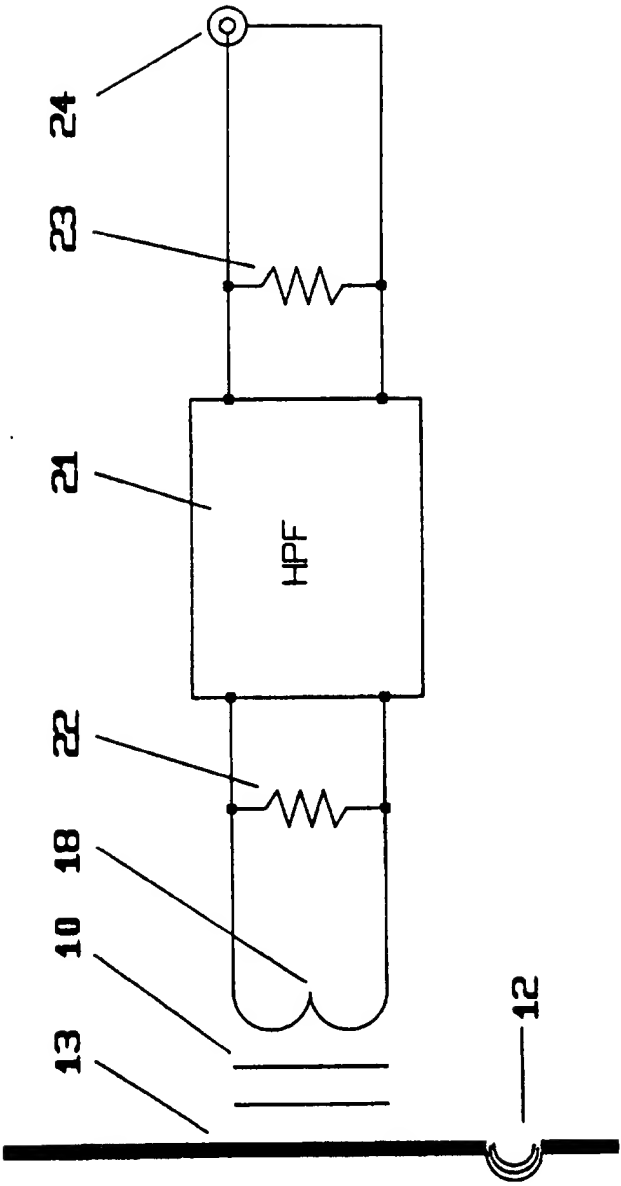


FIG-2

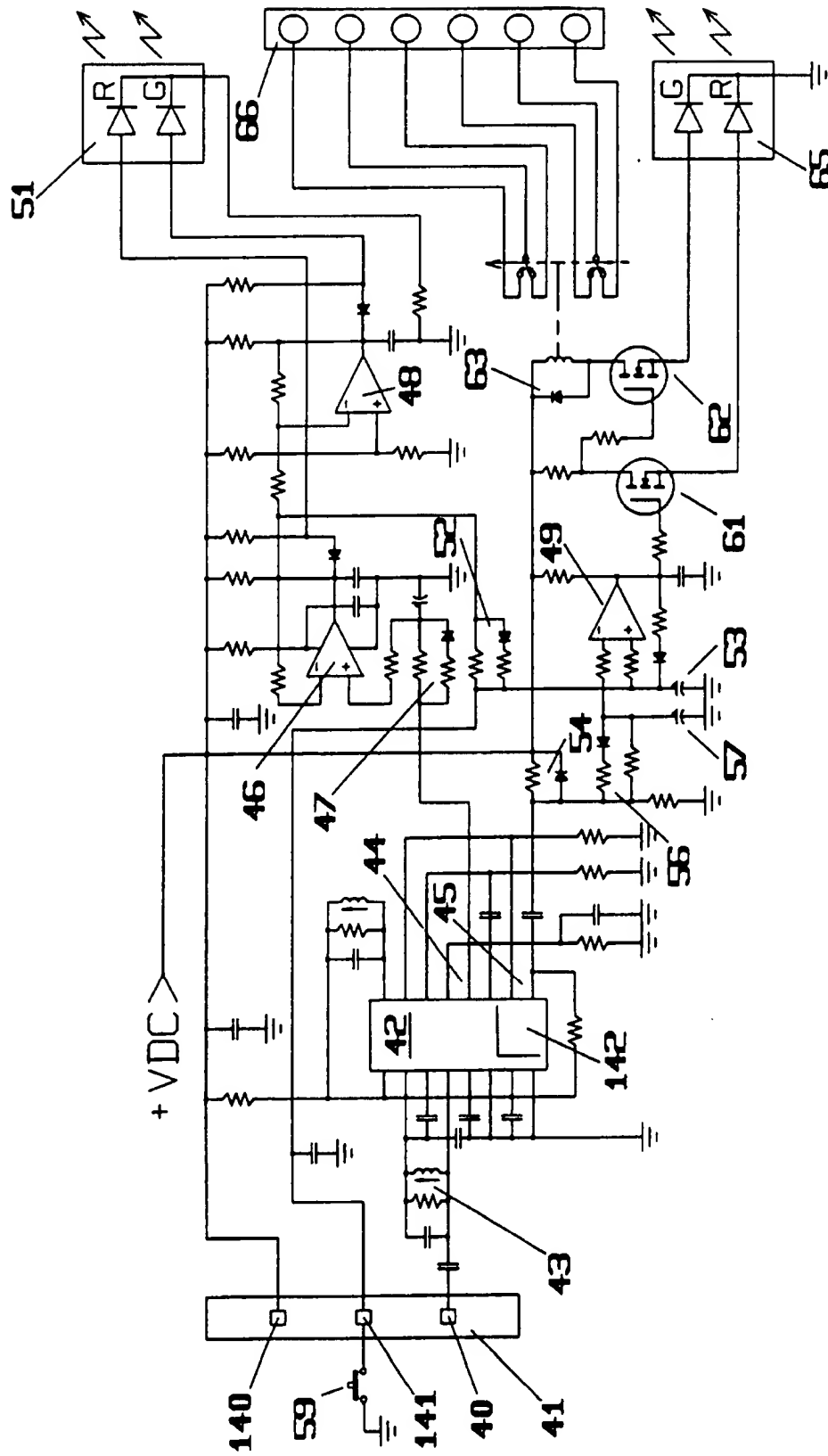


FIG. 4

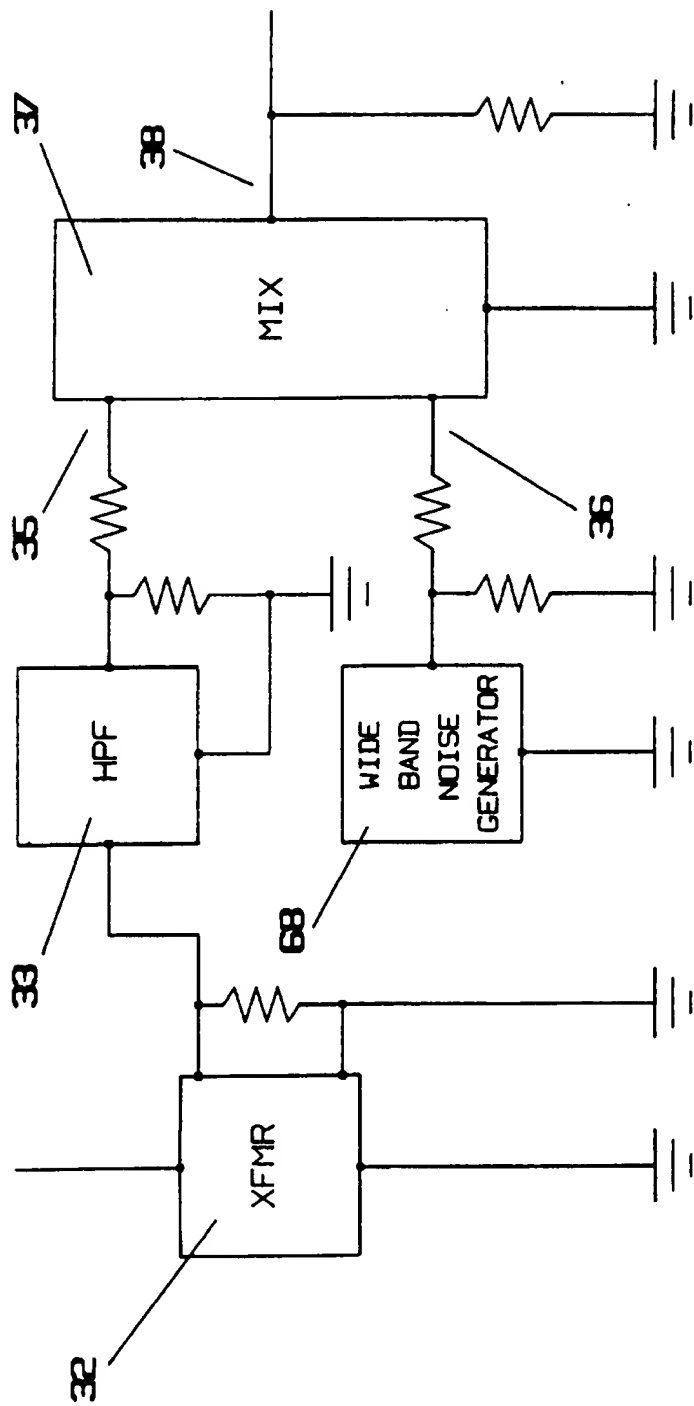


FIG-5